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OAR RESEARCH REVIEW

OFFICE OF AEROSPACE RESEARCH ★ UNITED STATES AIR FORCE

OAR: The Research Agency of the United States Air Force

Volume VII Number 12 December 1968

OAR RESEARCH REVIEW

VOLUME VII NUMBER 12 DECEMBER 1968

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ON THE COVER:

A crystal physicist at AFCRL's Solid State Sciences Laboratory holds a tube filled with gel in which electronically useful crystals are grown. The gel method of crystal growth permits crystals to be grown at room temperature. In many cases, such crystals can be grown more perfectly since the crystal-lattice structure is not distorted as in the case of crystals grown by high-temperature processes.

OARRP 80-1

OAR RESEARCH REVIEW is published monthly by the Office of Scientific and Technical Information (RRYC), Hq Office of Aerospace Research, USAF, 1400 Wilson Boulevard, Arlington, Va. 22209. The objective of this publication is to make a positive contribution to the exchange of information concerning Air Force conducted and sponsored research activities.

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ATMOSPHERIC DENSITY MEASUREMENTS WITH LASER RADAR

FRANK W. GIBSON, Aerospace Instrumentation Laboratory, AFCRL

With the advent of the laser as an intense source of electromagnetic radiation with unique properties, several possibilities for practical utilization emerged. The use of a laser radar to measure atmospheric density was deemed to be one of the more straightforward possible applications. Rayleigh scattering of light by air molecules was already well established. Experimental verification of the direct relationship between the intensity of backscattered light and atmospheric molecular density had been achieved by workers such as Elterman, (1) using searchlight techniques. The pulsed laser radar approach would provide a considerable improvement in these techniques in that it could present a virtually continuous profile of density variation with height as the transmitted pulse propagated through the atmosphere.

An investigation sponsored by AFCRL at the University of the West Indies, Kingston, Jamaica, to study the feasibility of measuring atmospheric densities has provided highly significant results and represents the most sophisticated such effort to date. Moreover, the utility of laser radar for the accurate measurement of molecular density, aerosol concentrations, and dust layers from 10 to 100 km on a routine basis is clearly apparent from preliminary data.

The basic theory for the scattering of light by air molecules was first developed by Rayleigh.(2) It can be shown (3) that, for the case of the pulsed laser radar, the backscatter photon count at the receiver is given by

$$C = \frac{n\rho_R}{h^2} \frac{\pi D^2 \tau c N_o T^2 Q}{8} \qquad (1)$$

where n = number density of molecules,
ρ_R = Rayleigh backscattering function,
h = mean height to scattering volume,
D = receiver diameter,
τ = receiver integration period,
c = velocity of light,
N_o = number of photons in transmitted pulse,
T = atmospheric transmission factor, and
Q = quantum efficiency of photodetector.

This relation shows that the number of photons received is a linear function of the atmospheric molecular number density and varies with the inverse square of the distance. The Rayleigh backscattering function, ρ_R, represents the fraction of light backscattered per unit path length, per unit solid angle, per molecule, per unit volume, and is given by

$$\rho_R = [4\pi(\mu - 1)^2]/n^2\lambda^4, \qquad (2)$$

where μ = index of refraction, and
λ = wavelength of light used.

$\rho_R = 1.98 \times 10^{-32}$ (meters)^2/steradian for the ruby-laser wavelength (λ = 6943 Å). Except for n and h, the remaining quantities in Equation 1 are constants for the particular equipment used. The number density decreases exponentially with height. This places an upper limit of around 100 km for density measurements with this technique because sky noise begins to predominate over the wanted signal.

A prototype laser radar system was constructed at the University of the West Indies.(3) Essentially, this equipment comprised a 3-joule ruby-laser transmitter ($N_o = 1.0 \times 10^{19}$ photons) and a 50-cm collecting mirror in a Newtonian optical arrangement. An EMI-9558 photomultiplier was used as the photon detector, the output of which was displayed in raster fashion on a Tektronix type-545 oscilloscope. By counting photon pulses from Polaroid pictures of the display, it was possible to determine relative densities between 10 and 70 km in close agreement with those calculated assuming a model atmosphere.

A more powerful and sophisticated system, which possesses nearly optimum performance capabilities, is now almost complete. The ruby-laser transmitter (Spacerays, Inc. Model 335) gives a total energy in each firing of about 11 joules ($N_o = 3.8 \times 10^{19}$ photons) in 10 microseconds. A reduction in the divergence of the vertically directed output beam is accomplished by reverse passage through a 15-inch telescope. The original 0.75-inch-diameter beam with a 25-milliradian divergence is expanded to a 15-inch diameter, and the divergence is reduced to 1.25 milliradians.

A mosaic of thirty 30-inch spherical mirrors, arranged so as to form a large concave surface with a diameter of approximately 20 feet and a focal length of 80 feet, serves as the primary collector of backscattered photons. This mirror array accepts the returned energy from the height range 45 to 100 km and operates in conjunction with a secondary receiver which uses only one 15-inch parabolic mirror (90-inch focal length) for the 15-to-45-km height range. In the primary system the energy is focused through a small receiving aperture and auxiliary optics and passed through a 20-Å filter and a specially cut prism to make multiple incidences on a pair of thermoelectrically cooled EMI-9558 photomultipliers. These components are located at an 80-foot elevation on a rigid tower structure and receive the backscattered radiation as it is reflected from a 45°-oriented mirror at the focus of the array. Because counting rates greater than 30 to 40 pulses per integration period (13.33 microseconds) leads to errors in the resolu-

tion of individual pulses, it is necessary to use 4 photomultipliers, each adjusted to cover a specific height range without being saturated at any point in it. The secondary system, using the single mirror, a pair of detectors, and a 3-Å filter, is mounted close to the transmitter and will be used primarily for daylight operation.

Experience with the prototype system revealed how very important the problem of noise reduction is if very weak signals (i.e., individual photons) are to be detected. The most severe noise sources are fluorescence from the laser and residual photomultiplier tube noise due to overexcitation of the cathode by the extremely intense pulse of light scattered by the lower atmosphere. It is therefore necessary to use mechanical shutters at the transmitter output and in front of the main photomultiplier, both synchronized with the laser firing.

The transmitter shutter is designed to close in about 150 microseconds (or 22.5 km), the wanted signal below this altitude being sufficiently intense to render the noise negligible. The shutter at the focus of the receiving optical system is closed during the firing of the laser and open immediately thereafter. However, to prevent an increase in the photomultiplier dark current due to a combination of fluorescence scattering from the first 22.5 km and the very strong signal from heights up to 30 or 40 km, this shutter is not fully open until 300 microseconds (i.e., 45 km). This means that measurements below 45 km are not made with the primary system, but with the secondary system.

The number of photons received from each consecutive height range of 2 km, for every firing of the laser, is counted and accumulated in a magnetic-core storage unit. A 3.33-microsecond period (0.5 km) is allowed for processing the count. The counts from each firing are automatically added to the previous counts recorded, for 64 height intervals. This corresponds to a total height of 160 km. The recorded information can be displayed visually and also permanently recorded by a high-speed print-out unit. After about an hour's operation (300 shots), it is expected the sytem can process sufficient information to give an accurate relative density profile. A block diagram of the complete system is shown in Figure 1.

Results from the initial tests using the high-sensitivity system are shown in Figure 2. These data were taken with only 12 mirrors installed and 1 photomultiplier in operation. Nevertheless, this incomplete system is more sensitive than previous operating systems by a factor of at least 50. Figure 2 shows a plot of the range-normalized scattering index Ch^2 vs. height, obtained from a typical run of 100 shots of the laser radar. Since the scattering

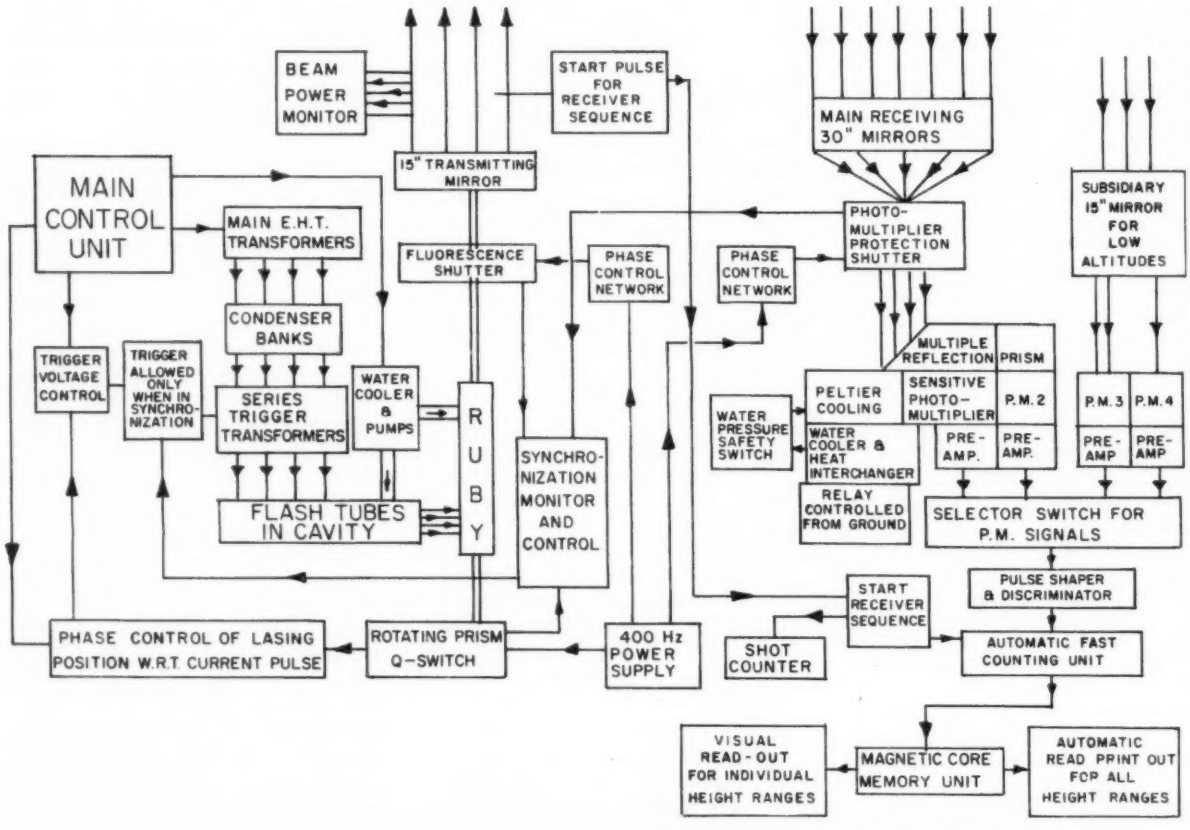

Figure 1. Over-all block diagram of complete laser radar system for measurement of atmospheric densities.

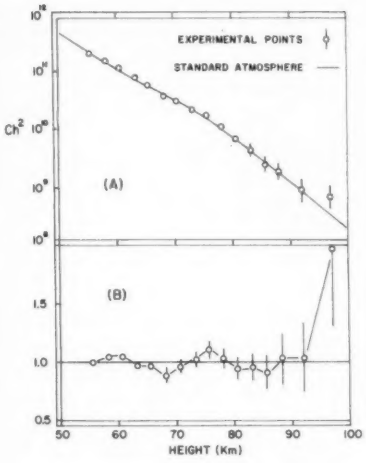

Figure 2. Variation with height of (A) observed scattering index, and (B) ratio of experimental values to Standard Atmosphere.

index is proportional to atmospheric density, a logarithmic plot of Ch^2 should decrease linearly with height. The error bars indicate the statistical error inherent in measuring a quantum signal. Accuracies within 1% at 50 km and 10% at 80 km are obtained with the radar in its present configuration. Reported accuracies from rocket measurments range from within about 5% at 30 km to 8% at 80 km. (4)

Since an absolute calibration is difficult, relative data are presented and the results in Figure 2 are fitted to the U.S. Standard Atmosphere for lat. 15° N. around a height of 60 km. With the introduction of switched photomultipliers to extend the dynamic range down to 30 km, it will be possible to calibrate by comparison with balloon measurements. Moreover, the complete system, with improvements in operational procedures, should give an eventual accuracy of within 10% or better at 100 km.

Probably the most significant result of this first series of runs is the lack of evidence of appreciable scattering from dust throughout the height range from 55 to 100 km as has been reported by some investigators. (4) For some time this has loomed as the most serious limitation on the use of laser radar for high-altitude molecular-density measurements, due to the fact that the latter would be obscured by the dust scattering. This does not suggest that latitudinal variations in dust concentrations may not occur, but rather that they are easily identified with this kind of system, and would not preclude density measurements. In any case, it is very clear that large laser radars offer a new and powerful technique for examining atmospheric properties and dynamics in the 10-to-100-km height range on a routine basis. Finally, accuracies achievable with this technique compare favorably with the best available, and at a considerable reduction in cost for extended periods of operation.

ACKNOWLEDGEMENTS

This work is being done at the University of the West Indies by Professor R. W. H. Wright, Dr. G. S. Kent, and Messrs. B. R. Clemesha and P. Sandland under Grant No. AF-AFOSR-616-67.

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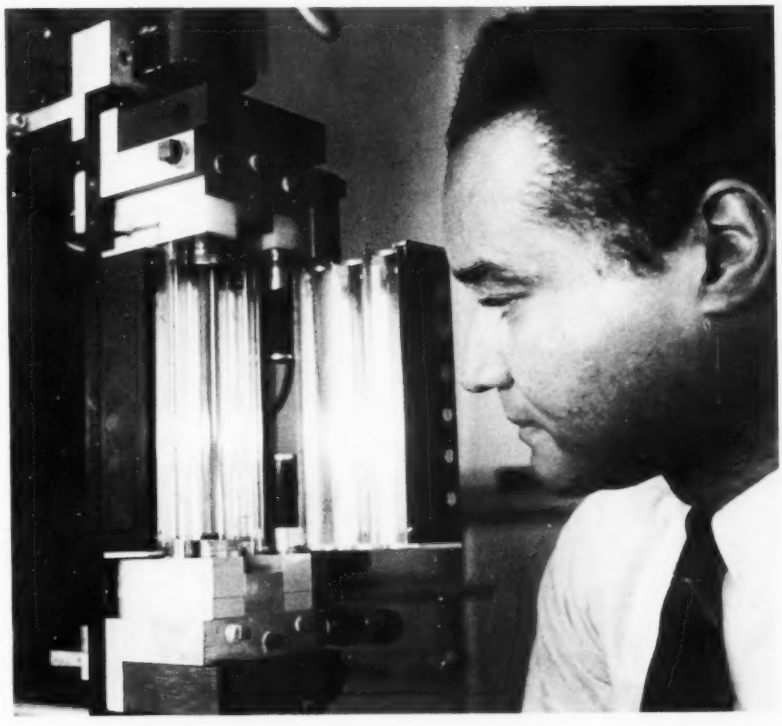

Mr. Frank W. Gibson is a research physicist at the Meteorological Observing Techniques Branch, Aerospace Instrumentation Laboratory, AFCRL. He received his B.S. in Physics from Morehouse College in 1955, and subsequently pursued graduate studies in physics at Northwestern University and Boston University.

Mr. Gibson's military service was spent as a physicist in the Aeroballistics Laboratory, Army Ballistic Missiles Agency (now NASA Marshall Space Flight Center), Huntsville, Alabama. He joined AFCRL in 1960. Currently, he is involved in developing instrumentation for the indirect probing of atmospheric parameters, particularly in the application of laser radar techniques. He has several publications to his credit.

TROPOSCATTER EXPERIMENTS AT 15.7 GHz DEFINE STRUCTURE OF TROPOSPHERE

MICROWAVE
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AFCRL's 29-foot millimeter-wave antenna.

The fine structure, minor variations, and turbulent dynamics of the troposphere up to altitudes of 40,000 feet or so often go unrecorded by sensors carried aloft in balloons, rockets, and aircraft. Sensors on these vehicles provide only a fleeting picture of the situation at one instant of time. What is desired is a continuous record of the kaleidoscopic patterning over several-hour periods. Meteorologists and physicists may now have a significant new tool for measuring upper-tropospheric structure as a result of propagation experiments conducted by AFCRL and the Canadian Defence Research Establishment (DRTE).

In these experiments, a troposcatter propagation link operating at 15.7 GHz was established over a 500-km path between an AFCRL transmitter in Waltham, Massachusetts, and a DRTE receiver at Ottawa, Ontario. The operating frequency is the highest ever used for tropospheric scatter. The narrow beamwidths of the antennas permit the illumination of a very small volume of the troposphere. Although troposcatter is usually identified with communications, the AFCRL-DRTE experiment demonstrated a possible new role in research instrumentation. Computer-stored recordings of the received signal—up to 50 db above the noise—contain a wealth of data on the structure of the troposphere.

The AFCRL-DRTE link has been in operation since April 1968. Drs. Edward E. Altshuler and Uve H. W. Lammers of AFCRL, together with John W. B. Day and K. Stewart McCormick of DRTE, have reported several interesting features of the troposphere observed during several test periods.

The AFCRL and DRTE scientists found regions of weak and strong

reflections, which they interpret as a layering of the troposphere, with the layers parallel or inclined to the earth's surface. The alternate strong and weak reflections are caused, most likely, by sharp gradients in refractive index. The layers seem to be about 2 km thick, with as many as 4 such layers having been recorded. At times the tropopause was clearly visible at a height of around 12 km. The layering and the clearly defined tropopause remain relatively stationary during a 10-minute observation period. However, observations made 1 hour apart seldom show the same structure.

Tropospheric structure is resolved by beam-swinging the antennas under computer control. With a synchronization accuracy better than 100 milliseconds, both antennas scan the common illumination volume (the intersection of both antenna beams) to produce a raster pattern similar to that used to generate a TV picture. Different views of the troposphere and its temporal variations can be obtained by "slicing" the troposphere along the propagation path, perpendicular to it, or parallel to the earth's surface. Dynamic information on the troposphere was obtained through the Doppler shift and frequency spread of the highly stable and spectrally narrow transmitted signal. Doppler and spreading effects are caused by wind speed and turbulence with the well-defined scatter volume.

The 2 antennas used in the experiments were AFCRL's 29-foot millimeter-wave antenna atop Prospect Hill in Waltham, Massachusetts, and the DRTE 30-foot antenna at Shirley Bay, Ottawa. The antennas are horizontally polarized with a 60-db gain and free space beamwidths of 0.14 degrees, which led to a common volume of about 0.7 km wide and high, and 10 km long. The transmitter generates 2 kw of c-w power, and the receiver can detect signals at −140 dbm (decibels below one milliwatt). Signals monitored with fixed antenna positions over 24-hour periods were stronger in the late afternoon than in the morning. However, they could generally be detected most of the time, day and night, except for very short periods during which deep fading occurred.

Dr. Edward E. Altshuler (left) and Dr. U. H. W. Lammers examine tropospheric scatter propagation data.

Dr. Edward E. Altshuler is Chief of the Millimeter Wave Branch of AFCRL's Microwave Physics Laboratory, where he is presently supervising research at millimeter wavelengths to obtain basic knowledge on (1) the lower atmosphere and its effect on propagation; (2) the behavior of active regions on the sun and their interaction with solar flares through high-resolution observations; and (3) the gross surface properties of the moon and near-in planets.

Dr. Altshuler received his B.S. in Physics in 1953 from Northeastern University, his M.S. in Physics in 1954 from Tufts University, and his Ph. D. in Applied Physics in 1960 from Harvard University. He has previously worked as an engineer at Sylvania Electric's Avionics Laboratory and Missile Systems Laboratory, and also as Manager of Research and Development with Gabriel Electronics at Millis, Mass.

Dr. Altshuler is a member of IEEE, Sigma Xi, and RESA, and has a number of publications to his credit.

Dr. Uve H. W. Lammers is a research electronics engineer in the Millimeter Wave Branch of AFCRL's Microwave Physics Laboratory, where he is presently working on tropospheric propagation studies of microwaves. From 1955 to 1965, he studied electrical engineering at the Institute of Technology, Hanover, Germany, and the Technical University, Berlin-Charlottenburg, Germany. He received his M.S. in 1961, and his Ph.D. in 1965, both in Electrical Engineering and both from the Technical University.

Dr. Lammers was formerly associated with the Heinrich-Hertz Institut, Berlin-Charlottenburg, where he was primarily engaged in tropospheric propagation of short millimeter waves. He has received two awards for inventions related to his area of research.

testing SPARSA, a system for detecting atmospheric electricity

AEROSPACE INSTRUMENTATION LABORATORY, AFCRL

Electrical storms bring with them a special threat to our missile ranges at Cape Kennedy and Vandenberg AFB—particularly during fueling operations. This potential hazard led the Air Force in 1964 to ask AFCRL to develop a sferics (lightning) monitoring and detection system for installation in the Cape Kennedy area.

The system, known as SPARSA (Sferics Position, Azimuth, Range, Spectrum Analyzer), was first installed in the Cape Kennedy area in 1965. It is designed to monitor the growth and decay of active electrical centers. Bernard D. Weiss of AFCRL has reviewed SPARSA's performance in a recently issued report, "An Analysis of the Performance of the Three-Station SPARSA Network for Detecting and Tracking Thunderstorm Activity" (AFCRL-68-0272).

One would guess offhand that the weather radars and sferics monitors presently installed in the Cape Kennedy area could provide all the necessary information on electrical activity without the need for SPARSA's more specialized approach. And, to an extent, they do. But, with respect to radar, there is no one-to-one correlation between cumulus cloud build-up and sferics, and present sferics monitors do not provide directional information. These considerations led to the requirement for the more precise monitoring and tracking of sferics.

The AFCRL SPARSA system consists of 3 remote unmanned stations and a control center at Cape Kennedy, where the data from the stations are processed and displayed on an image storage tube. The 3 outlying stations are located 60 miles north, 40 miles west, and 35 miles south of the Cape, respectively. Each is designed to look only in the direction of Cape Kennedy. Together, they monitor a circle 40 miles in diameter.

Equipments at these remote stations are designed to detect 500-kHz EM pulses from sferics. The number of sferics per minute is counted as the measure of sferics activity, rather than the intensity of the pulses. Pulse rates below about 20 per minute are ignored. Six sensitivity threshold levels were established to prevent system saturation, with the highest threshold setting being at a count rate above 580 pulses per minute.

For the test program, it was necessary that results be checked against other data, for purposes of verification. Five verification sources were used. One was the CPS-9 weather radar at Patrick AFB, 15 miles from the Cape. Others were surface weather observations from stations in and around the area, volunteer observers residing in the area, conventional sferics monitors (TSM/C), and the DAED equipment located at Cape Kennedy for detecting atmospheric electric disturbances.

At each of the central monitoring stations, a triangulation display console houses an image storage tube. When sferics are detected above a given count rate at one of the three stations, a pie-shaped wedge extending outward from the station is depicted on the display, with the width of the segment depending upon the extent of the sferics activity. When a similar wedge from one of the other stations crosses the first, a fix is obtained on the area of maximum sferics activity.

The test program which Weiss discusses in his 200-page report was conducted during July and August 1967, a period during which there were 79 thunderstorms. The results show that the SPARSA system has several distinct advantages over radar and other electrical-activity-monitoring techniques: 1) it can locate the areas of most intense electrical activity with greater precision; 2) it provides earlier warning of incipient electrical activity; and 3) it provides earlier warning of the dissipation of thunderstorms and electrical activity.

Mr. Bernard D. Weiss, a meteorologist in the Equipment Engineering and Evaluation Branch of AFCRL's Aerospace Instrumentation Laboratory, performs extensive field tests on meteorological equipment to determine its accuracy and reliability. The objective is to improve meteorological instrumentation, observational techniques, and data-reduction methods.

Mr. Weiss received his B.S. in Mathematics from the University of Miami. From 1947-51 and 1954-60, he was with the U.S. Weather Bureau, serving as Supervisor of the Rawinsonde Station in Keflavik, Iceland, and as a meteorologist in both the arctic and antarctic regions. From 1960-62, he was a Supervising Meteorologist with the Air Weather Service. He is a member of the American Meteorological Society.

Mr. Bernard D. Weiss evaluates output data of SPARSA equipment located at Cape Kennedy, Florida.

MEASURING SEISMIC NOISE AT THE SITE OF AN ELECTRONICS RESEARCH CENTER

TERRESTRIAL SCIENCES LABORATORY, AFCRL

If you live in the city, you are surrounded by seismic noise. The noise of jets overhead is translated into seismic vibrations on the earth's surface, the activities of people themselves create seismic noise, and subways beneath the earth and large trucks on the street can set off relatively giant vibrations. But just how noisy is any particular location in a city?

The particular location of interest to NASA, for example, is the Kendall Square area near MIT in Cambridge, Mass. There NASA will erect new facilities for its Electronics Research Center (ERC). The reason for NASA's concern with seismic noise is that tests of precision guidance equipment involving gyros and accelerometers and optical instruments require a seismic noise-free environment.

Because AFCRL's seismic research programs have produced a number of sensitive seismometers, together with techniques for measuring microseismic waves, NASA has called on AFCRL to define the seismic conditions in the Kendall Square area. To make the measurements, Francis A. Crowley of AFCRL, who is directing the program, has established several test sites, each with an 18-element array. Determination of soil transmission characteristics in the ERC laboratory area has involved the detection of phase velocities and the coherency of seismic propagation across at least 3 of the seismic stations. This initial work was completed in June 1968. Last August, measurements were made of test piers. The objective of these tests was to monitor the seismic environment with seismometers physically located within 1 test pier. These data will be compared with the general seismic noise level of the area surrounding the piers. The results will indicate the relative efficiency of various pier designs in suppressing seismic noise.

deliberate distortion for improved intelligibility of transmitted speech

DATA SCIENCES LABORATORY, AFCRL

Let's say you have a $1,000 hi-fi system—$200 speakers, a $400 amplifier, and so on—with a 20,000-cycle frequency response. When you listen to speech through your rich, powerful speakers, the words may seem so mumbled that you are tempted to change the bass and treble settings in order to better understand what is being said. In changing the settings, however, you are changing your ideally flat frequency response to a distorted one. But you find that, once you have inserted the distortion, you don't have to strain to catch all the words.

This bears on a study recently completed by Maj John D. Griffiths of AFCRL. Griffiths' study is concerned with optimum intelligibility—with just how well the listener understands spoken radio- or telephone-transmitted messages. In transmitting voice messages, fidelity to the original speech is always degraded to some degree by compromises one must make with bandwidth, peak power or peak amplitude, and background noise. One must live with these constraints. Nevertheless, within these constraints, the standard of performance required by radio engineers is fidelity to the original speech. In this context, it becomes a violation of professional ethics to transmit a deliberately distorted signal; let those at the receiving terminal filter the signal in any way they wish; but it is the duty of the broadcaster to provide a clean, high-fidelity signal.

In a recently issued AFCRL report, "Improved Analog Voice Communications" (AFCRL-68-0227), Griffiths questions this traditional practice. First of all, he states that the primary criterion in establishing a voice circuit for military communications should not be fidelity, but intelligibility. The measure of merit is how well the message is subjectively understood. From this perspective, it is desirable to sacrifice fidelity to intelligibility. Griffiths suggests a simple method for improving the intelligibility of voice communications.

The reason for the apparent anomaly between fidelity and intelligibility is that different parts of the speech spectrum play disproportionate roles in transmitting speech information. Frequencies below about 3 kHz are much more important in speech transmission than those above. For this reason, most speech systems cut off at 3 kHz to conserve bandwidth. But, if we look at the different frequencies within the range of from about 200 Hz to 3 kHz, the highest peak-power levels seem to center about 400 Hz. Peak-power levels at 400 Hz are in fact about 5 times greater than those at 3 kHz. However, the frequencies at which consonants are enunciated are usually higher than 400 Hz, and clearly comprehended consonants are essential to good intelligibility.

This suggests that, if we put the power in speech where the information is, thus indirectly boosting the relative power of consonant components of speech, we can improve speech intelligibility. But isn't this exactly what is done when we increase the treble response at our receiver? It is, and it helps. But adjustments at the receiver are not optimum, for several reasons. These reasons involve normal

channel and receiver noise and the need to transmit the signal with a greater bandwidth than is really necessary. Griffiths shows that the equalizing filter should be at the transmitting terminal of the system, which not only overcomes certain inherent limitations of receiver filtering, but also permits the transmission of speech signals with less power.

The filter which Griffiths proposes would be placed in the microphone itself. A good equalizing filter could consist of nothing more than the addition of 2 appropriately valued resistors and a capacitor. The optimum filter raises the frequency response about 3.5 db for each octave above about 500 Hz. The gain in intelligibility is as if the transmitter power had been doubled.

Maj John D. Griffiths has been an electronics engineer since 1965 with AFCRL's Speech Research Branch, Data Sciences Laboratory, where he has been concerned with speech compression and research. He is presently testing optimal-filtering techniques and processing speech for transmission through noisy channels.

Maj Griffiths received his B.S. degree from the Massachusetts Institute of Technology in 1954, and his M.E.E. and Ph.D.E.E. degrees in 1961 and 1965, respectively, both from Syracuse University. Before entering the service, he was a recording engineer and an architectural acoustics consultant. Later, while in the service, he commanded the organization responsible for the engineering and installation of all USAF ground-based communications-electronics in the United Kingdom.

From 1958-61, Maj Griffiths was in charge of the speech-communications-research program at the Rome Air Development Center, AFSC. Also from 1961-62, he was a member of the Advanced Studies Office, where he studied space communications and wide-band modulation techniques. In 1962, he also made a study of all laser research then in progress within the USAF, with recommendations for certain adjustments in research emphasis.

Maj Griffiths is a member of IEEE and Sigma Xi, and has several publications to his credit.

Maj John D. Griffiths (right) and R. Frank Quick, MIT student, prepare master recording for use in testing speech systems.

SPACE PHYSICS LABORATORY AFCRL

the moon: a burnt-out cinder, or thermally active?

The moon is either a burnt-out cinder or, like the earth, it has a thermally active interior. There has not been much evidence to prove or disprove one view or the other. The question has been hotly debated for years, since the presence or absence of internal heat bears directly on such problems as the origin of the lunar craters and the vast dark "seas" that cover much of the visible disk. Observations made recently by three lunar astronomers at AFCRL's Space Physics Laboratory suggest that the interior of the moon may be thermally active.

The evidence supporting this view grew out of the analysis of infrared images of the lunar surface obtained during the lunar eclipse of 13 April 1968. The three AFCRL astronomers, Dr. Graham R. Hunt, Dr. John W. Salisbury, and 1st Lt Robert K. Vincent, reported their results in the 11 October 1968 issue of *Science*.

Using AFCRL's 24-inch telescope at Concord, Mass., they obtained a number of infrared images with a scanning device having a liquid-helium-cooled, copper-doped germanium detector. Observations were made in the 8-to-14-micron range. Using a thermal-enhancement technique developed by Dr. Hunt, the 3 astronomers were able to obtain the highest resolution images of the moon yet made during a lunar eclipse.

During the brief hour or so of an eclipse when the earth shadows the moon, sensitive infrared instruments can record hundreds of hot spots on the moon. Previous experiments by the three AFCRL astronomers had shown that most of these hot spots are simply areas of reradiated solar heat that has been stored in the lunar surface materials.

But examination of these new eclipse infrared images uncovered an interesting thermal anomaly in Mare Humorum, a small circular sea in the southwestern portion of the lunar disk. Unlike most hot spots, this anomaly extends quite some distance along a line and coincides with a crustal fracture more than 100 miles long on the western "shore" of this mare. In the late lunar afternoon,

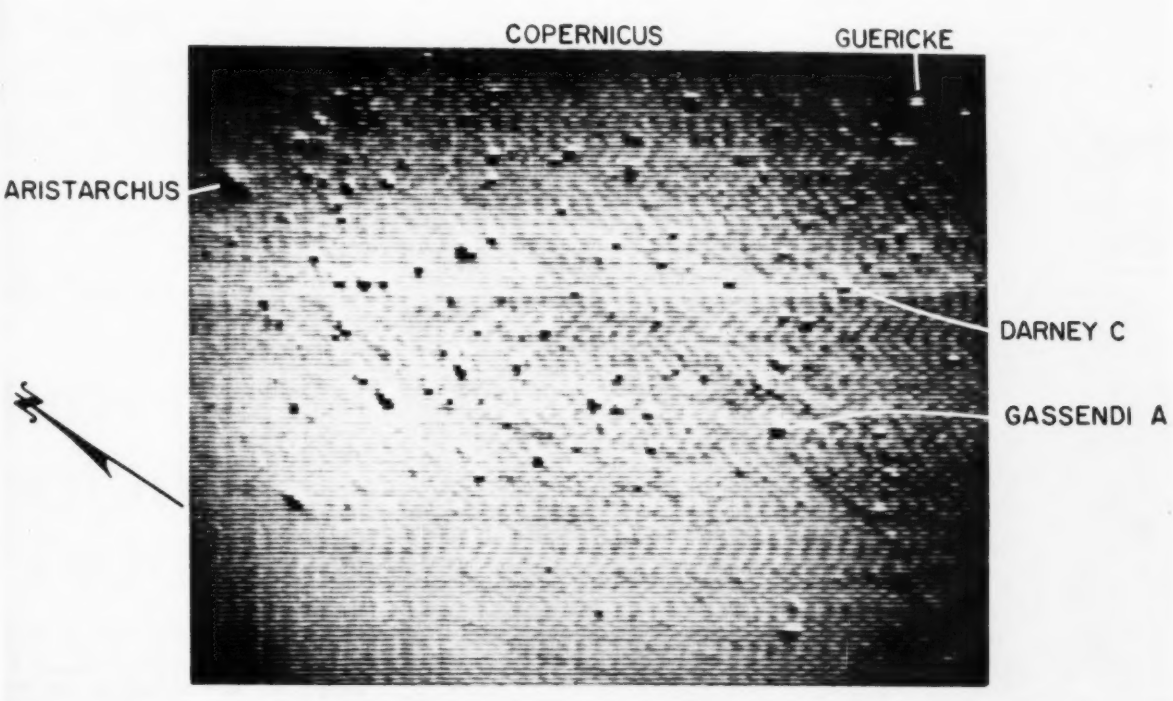

Figure 1. This photo shows an infrared scan of the lunar surface. The hot spots are clearly seen in the small black dots in the picture.

when the areas on either side of this fracture had begun to cool, this area remained warm.

The thermal activity associated with this fracture was unlike that of any of the other hot spots measured. There could be a number of explanations for this thermal anomaly. In their *Science* paper the AFCRL scientists, whose respective specialties are geology, spectroscopy, and physics, considered as one possible explanation the heat-absorption property of materials along the fault compared with that of the materials on either side. Another possible explanation was the longer exposure of the area to solar heating due to elevation or the angle of escarpment to the sun. However, evidence led them to discount these possible explanations. They concluded that the most reasonable explanation for the thermal anomaly is an internal heat source.

They then gave supporting evidence for this conclusion. The location of the anomaly along a line of crustal fracture suggests a natural access to an internal heat source, as in the case of fracture regions on earth. Slow leakage of hot gases to the surface along the fault zone could provide an efficient heat-transport mechanism. In this regard, it is significant that there are at least 4 dark-haloed craters along the fault line, features which are generally considered to be due to gas explosions of internal origin. Also of interest is the fact that at least 12 reddish flashes or patches have been reported in the general area of the fault during the last 2 years. Taken together, the thermal and geological evidence strongly suggests an internal origin for this thermal anomaly. The 3 AFCRL scientists are seeking conclusive proof of its origin in further telescopic observations.

1st Lt Robert K. Vincent is a general physicist at AFCRL's Space Physics Laboratory. He attended Louisiana Polytechnic Institute at Ruston, Louisiana where, in 1963, he received a B.S. in Physics and B.A. in Mathematics. In 1966 he received his M.S. in Physics from the University of Maryland, where he held both teaching and research assistantships. During the summer of 1961, Lt Vincent worked for the United Gas Research Laboratory in Shreveport, Louisiana, assisting in the development of an electroscanner computer. The summers of 1963, 1964, and 1965 were spent at Texas Instruments, Inc., Dallas, Texas, where he did basic research on the diffusion process in semiconductors and designed a very-low-current germanium transistor. Lt Vincent is a member of the American Institute of Physics.

Dr. John W. Salisbury is Chief of the Lunar-Planetary Research Branch at AFCRL's Space Physics Laboratory. He has been with AFCRL from 1959 to the present, becoming Chief of the Lunar-Planetary Research Branch in 1961. In this capacity, he directs a program of research concerned with the nature of both lunar and planetary environments. His own research is involved primarily with the origin of lunar-surface features and the composition and nature of lunar-surface materials.

Dr. Salisbury attended Amherst College where he received his B.A. (magna cum laude) in Geology in 1955, and was elected to Phi Beta Kappa. He also attended graduate school at Yale University, receiving his M.S. in 1957 and his Ph.D. in 1959, both in Geology.

Dr. Salisbury is recipient of the Outstanding Contribution to Military Science award for 1961.

Dr. Graham R. Hunt is a physical research chemist at AFCRL's Space Physics Laboratory, where he has been since 1963. His work has been concerned with the application of spectroscopic and radiometric imaging techniques in order to obtain information on the composition and nature of lunar and planetary surfaces. He has a B.Sc. (Hons) (1952), an M.Sc. (1954), and a Ph.D. (1958), all in Physical Chemistry, and all from Sydney University, Sydney, Australia.

Prior to joining AFCRL, Dr. Hunt was employed by the Massachusetts Institute of Technology in the spectroscopy department. There he used the large echelle spectrograph to study visible and near-ultraviolet systems of NO_2, and designed far-infrared vacuum spectrometers to study solid-state spectra. From 1960 to 1962, he was employed in the Chemistry Department of Tufts University. He is the receipient of a number of awards and the author and coauthor of several papers.

From left to right, 1st Lt Robert K. Vincent, Dr. John W. Salisbury and Dr. Graham R. Hunt of AFCRL discussing various data resulting from their investigation of hot spots on the moon.

"Detection, precise location, and quick destruction of enemy units in Vietnam are the most pressing problems facing DoD's research-and-development experts in their support of the war in Southeast Asia."

These were the words of Dr. John S. Foster, Jr., Director of Defense Research and Engineering, in testimony before the Senate Armed Services Committee.

There is little doubt but that detection is the the most pressing of the problems mentioned, although the others are of great importance once the enemy is detected. Conceivably, the enemy could be located by one or a combination of several means–means utilizing odor, temperature, color, and/or sound.

Promising assistance in this important area is expected with the application of a unique type of material known as liquid crystals. AFOSR has for several years nurtured basic research on these materials. In fact, a prime contribution toward stimulating new research was AFOSR's sponsorship of the First International Conference on Liquid Crystals at Kent State University (Kent, Ohio) in 1966. A second such international conference, also under AFOSR sponsorship, was held in August 1968. In addition, AFOSR's Directorate of Chemical Sciences has been the project office for a joint project, with Advanced Research Projects Agency funding, between the Liquid Crystal Institute at Kent State University and the Westinghouse Research Laboratories. This particular project calls for basic studies of liquid crystals as related to electro-optical and other devices.

Because of AFOSR's continued interest in the liquid-crystal field, AFOSR was recently selected to monitor a top-rated Themis program awarded to Kent State University for the study of "Physical and Structural Properties of Liquid Crystals and Their Potential Application as Detectors."

In light of the continued interest, it seems appropriate to give a brief description of liquid crystals, pointing to those fundamental properties which make their application in detection devices, as well as other applications, so promising.

An Austrian botanist, Frederick Reinitzer, is credited with the discovery of the "liquid-crystalline" state, which he described in the chemical literature in 1888. He found that cholesteryl benzoate, the compound which he had prepared, appeared to have two melting points. At 145° C the solid structure collapsed to form a turbid liquid which became transparent when heated to 179° C. Shortly thereafter, the German physicist, O. Lehmann, showed that the cloudy intermediate phase contained areas that seemed to have a crystal-like molecular structure. He suggested the name, "liquid crystal," for this phase.

Liquid-crystal research reached a peak during the early 1930's. In addition to having attracted dozens of experimenters, who turned up many new liquid-crystal substances, the field had attracted such eminent theoreticians as W. H. Bragg, Louis de Broglie, and Max Born. In spite of this flurry of activity, interest soon waned and, for the next 30 years, virtually no important work was done on the liquid-crystal phase. Several factors contributed to this period of quiescence. One was apparently the general feeling among physicists that all the important problems in the field were solved and only minor difficulties remained. Another was the tendency of almost all writers of general texts on physics and chemistry to ignore the liquid-crystal phase altogether, as a result of which many modern workers are only vaguely aware that an ambiguous melting point can be attributed to something other than impurities in the substance being tested. Perhaps the most important reason for the waning of interest in liquid-crystal research, however, was the apparent lack of practical applications. The importance of this can be appreciated if one considers that the spectacular development of solid-state physics in the past two decades has been stimulated largely by the promise of prompt technological dividends.

In 1957, Professor Glenn H. Brown, then at the University of Cincinnati, coauthored a paper on "The Mesomorphic State–Liquid Crystals" in *Chemical Reviews.* This seemed to create a resurgence of interest in this field. In 1958, J. L. Fergason and colleagues at the Westinghouse Research Laboratories began research aimed at learning more about the molecular structure, optical properties, and technological possibilities of liquid-crystal substances. Both Brown and Fergason are now active at the Liquid-Crystal Institute at Kent State University, where they are combining their efforts to further the field of application of liquid crystals.

Because of the incompatibility of the term's components, it seems almost obligatory to give some explanation of what is meant by the hybrid

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LIQUID OR SOLID, "LIQUID CRYSTALS" HAVE MANY APPLICATIONS

term, "liquid crystals." Other names that are probably more definitive are also used–mesomorphic state, anisotropic liquids, paracrystals, crystalline liquids, etc.–but it appears that the term, "liquid crystal," has been more generally accepted.

These substances, as inferred, exist in states where they are neither solid nor liquid, but somewhere "in between." Although the existence of these substances has been known for a number of years, it has only been with the appearance of modern equipment capable of probing inside the solid and liquid states that scientists have begun to examine these "in-between" states more closely to learn more about their properties. It is these intermediate states which make liquid-crystalline compounds unique.

Liquid-crystalline structures are referred to as nematic, smectic, and cholesteric. This sytem of classification was proposed by G. Friedel in 1922.

In the nematic structure, the only restriction as to the arrangement of the molecules is that they preserve an arrangement wherein they are parallel to each other. The molecules have mobility in three directions, with rotation about one axis being permitted. (See Figure 1.)

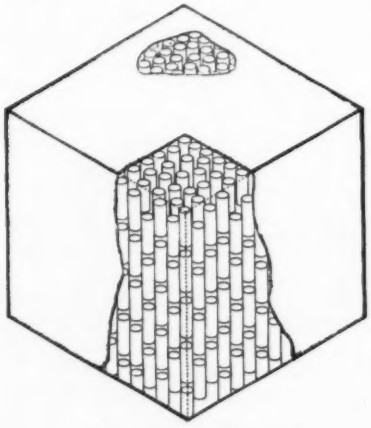

Figure 1. Nematic structure.

The smectic structure is stratified, the molecules being arranged in layers with their long axes approximately normal to the plane of the layers. The molecules can move in two directions in their plane and can rotate about one axis. The molecules in the smectic structure may be ordered in neat rows within individual layers, or the molecules within a layer may be randomly distributed. (See Figure 2.)

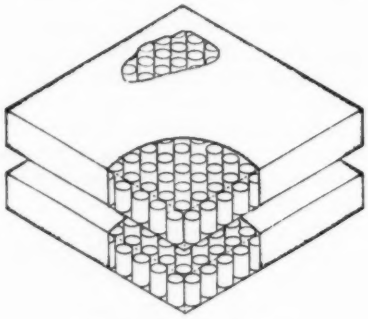

Figure 2. Smectic structure.

The cholesteric structure is found primarily in derivatives of cholesterol, especially the esters. The material consists of layers which are about 2,000 angstroms thick and are parallel. While most of the individual molecules in the cholesteric state are essentially flat, side chains project upward from the plane of each molecule while some hydrogen atoms extend below. Thus, the direction of the long axis of the molecule in a chosen layer is slightly displaced from the direction of this axis in adjacent layers. The resultant displacement produces a helical design. (See Figure 3.)

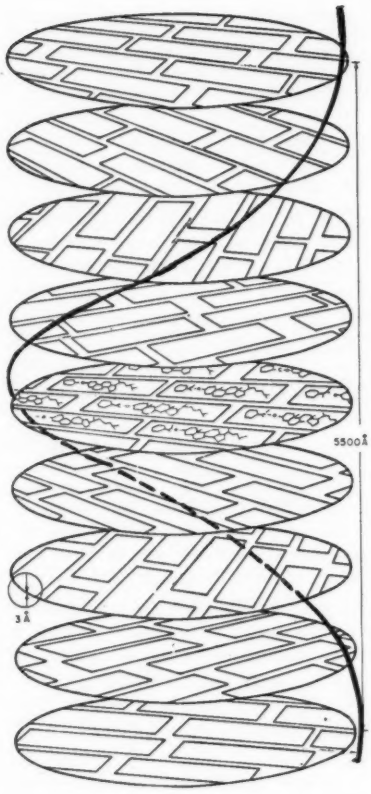

Figure 3. Cholesteric structure.

At present, organic compounds are the only ones known to exhibit the liquid-crystalline state. One cannot lay down hard and fast rules concerning the kind of molecules which will form liquid crystals, but the general relationship between molecular geometry and liquid crystallinity can be established.

The molecules are elongated, relatively straight and, in some cases, flattened. This shape favors a parallel alignment of the molecules, like bundles of pencils. Molecules which form liquid crystals have dipoles in their structure; and often there is a strong dipole toward the center of the molecule and weak dipoles toward the end of the molecule.

Historically speaking, liquid crystals were discovered because of the optical properties of the cholesteric liquid-crystal state. Since the potential application of cholesteric structures is more apparent, they will be discussed in more detail. Early studies showed that these structures are optically positive. The cholesteric structure is optically active with rotary powers many times those of inherently optically active materials; and, when illuminated with white light, it scatters the light to give an iridescent color, which varies with the substance, the temperature, and the angle of the incident beam.

The optical properties depend on a delicately balanced molecular aggregation. A change of shape or dipole moment or any other disturbance which interferes with the weak forces between molecules results in a dramatic change. Reflection, transmission, birefringence, circular dichroism, optical rotation, color–can all undergo marked transformations with changes in temperature, pressure, electric field, chemical environment, etc. These

changes are peculiar to the liquid-crystal state, since it is only in this state that the centers of gravity of the molecules are not fixed and thus not bound by rigid geometric principles.

Perhaps the most striking transformations of the optical properties of the cholesteric phase are those due to temperature changes. Although cholesteric materials are substantially colorless in the anisotropic liquid phase, when cooled through their clearing temperatures some pass through a series of color changes when viewed in reflected light. In this transition phase, they appear first as violet, then blue, green, yellow, red, and finally colorless, as they enter the infrared region.

All cholesteric liquid materials do not respond in this same way to temperature changes. They have a remarkable property, however, in that each color corresponds to an exact temperature of the material being measured. The rate of change of color, the temperature at which specific colors occur, as well as the direction of shift, are all predictable. Thus, a desired combination of factors can be obtained by varying the materials and their combinations.

Regarding the variety and purity of color, the response of cholesteric liquid crystals to chemical vapors resembles the response to temperature change, although the two effects may be compeletely independent. With the addition of chemical vapors, a change occurs in either the Van der Waals forces or the simple dipole forces. This change in molecular arrangement, in turn, affects the unique scattering properties of the cholesteric liquid crystals. If the liquid crystals serve as a solvent for the gas, the color effect will be reversible. However, if the gas reacts with the liquid crystals or serves as a catalyst, the color change will be permanent.

The addition of an irreversibly compatible solute results in a far more drastic change in molecular packing than does the addition of a reversibly compatible solute. Just as a single dislocation in a polycrystalline solid may alter the geometry of the entire grain, a change in a single molecule affects the entire optical response of a given domain in the anisotropic liquid.

The molecular packing of cholesteric liquid crystals is also altered by mechanical stress. Since intermolecular binding forces are weak, it may be expected that mechanical distortion would have a more pronounced effect on these liquid crystals than it has on solids and liquids which respond optically to mechanical stress. The optical properties can, in fact, be changed in a rapid and predictable manner by the application of a small mechanical stress. These optical effects are proportional to the rate of shear. At low shear rates, the color change is small; and, if the shear rates are constant, the color will remain constant.

In addition to temperature, chemicals, and shear stress, there are numerous other physical conditions which produce marked changes in the optical properties of cholesteric liquid crystals. A polar field can activate the dipolar character of cholesteric derivatives. Radiation can generate chemical changes, producing effects similar to the irreversible effects resulting from the addition of certain chemicals. A combination of physical environments will generate a combination of optical responses.

Now that some of the unusual properties of liquid crystals have been pointed out, it seems appropriate to briefly discuss some of their potential applications. One of the more obvious concerns the manner in which temperature changes can cause incident white light to be reflected in a variety of colors. The liquid crystals may thus be used to display colored images for information transmittal. Applications are also foreseen in an erasable, reusable photographic film.

Other potential devices on the shear-sensitivity property, besides color display devices, could include an acoustical-drive high-speed light chopper for laser modulation, a visible rate gyro for airborne and space bank-and-turn indicators, and shear-rate indicators for dynamic testing. Since major changes occur in the optical properties of cholesteric liquid crystals when chemicals are added, it becomes obvious that this phenomenon could be put to use as a tool in chemical analysis.

Success has been evidenced by the thermal mapping of the human body in which liquid crystals are applied to the surface of the skin to locate veins and arteries that would transmit heat at a rate different from that of the surrounding tissue. Cancerous tumors, the degree of burns, and a lack of circulation in maimed limbs will lend themselves to detection and examination by means of liquid crystals.

Liquid crystals are also capable of detecting various vapors with a shift in color. A liquid crystal might detect the unburned hydrocarbons associated with carbon monoxide, thereby serving as an inexpensive warning device. Undoubtedly, as scientists and engineers become more and more familiar with liquid crystals, many other applications will be found.

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WORLD DIVERSITY IN HUMAN BODY SIZE AND ITS MEANING IN AMERICAN AID PROGRAMS

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American travelers returning home from other lands are often struck by the largeness of our people as compared with people of other nations. The keener observers even claim to notice differences in body proportion.

Are Americans really giants among the world's populations? For at least a partial answer we have compared some Mediterranean and Oriental populations with an American sample–selected because they all have been studied according to the same measuring techniques. The findings of this inquiry show that Americans really are among the largest-bodied people in the world; and this fact can have far-reaching implications, especially in terms of the clothing and equipment our nation furnishes under its Agency for International Development (AID) or military aid programs.

Everybody can see that there are differences of body size and body proportion among human beings. We know–from the most ancient writings, and from still more ancient rock paintings–that people have recognized such differences since very early times. But the measurement of those differences is something relatively new in man's "immense journey," while man's efficient use of such data for his own benefit, especially on any international scale, has hardly begun.

This should cause no wonder, since no national population has been measured in detail in a scientifically chosen national sampling. ("In detail" here means that about 100 or more dimensions have been measured on a mass sample by standardized techniques.) One special subpopulation, however, has been intensively studied for a quarter of a century– the flying personnel of the U.S. Air Force. For example, in the Air Force's last-published anthropometric survey, conducted in 1950, 132 dimensions were taken on each of more than 4,000 crewmen. (1) In the most recent Air Force survey, conducted between 1965 and 1967, but not yet ready for publication, as many as 187 dimensions were taken.

Most people are not aware of the problems inherent in measuring the human body. It seems so simple that anyone should be able to do it. The difficulties show up only when two or more measurers try to get the same results on the same subject. This requires high skill and standardized techniques, because the male human body normally has a rather wedge-shaped or tapering cross section. To obtain the same values repeatedly–that is, to insure that the techniques are standard–the precise location of measuring instruments is important, and so is the degree of pressure applied on compressible flesh. Still more important is the subject's body position, because some dimensions can vary astonishingly with even small changes in limb position. Thus, a subjects's shoulder breadth changes rapidly as his arms move from their normal hanging position; his biceps circumference is larger when the elbow is bent than when it is straight; and his hip breadth is greater when he sits than when he stands. Hence, anthropometric data taken by different investigators, to be strictly comparable, must be taken in standardized ways.

Although some long-established measuring procedures were standardized in the first decade of this century, new practical problems since World War II–such as cockpit dimensions, sizes for mass-produced pressure garments, and the like–have continued to demand new measurements of the human body for new applications; and the number of these has multiplied manyfold in the past two decades. Since no real standardization of modern anthropometric techniques has yet been achieved (although steps have been taken to standardize them), not all sets of anthropometric data from diverse sources are fully comparable.

One has to remember these factors when comparing data from different parts of the world. Technical differences can cause apparent discrepancies in the data that do not actually exist among the people, or they can mask differences that are real. The cold numbers alone cannot resolve the possible ambiguity. In this situation we are fortunate that Air Force anthropologists, using the same techniques, have measured military personnel in Turkey, Greece and Italy (2), and have trained a measuring team in Japan. (3) Further, the Air Force anthropometric manual (1) was followed in meticulous detail on a sample of pilots in the Republic of South Korea. (4) Hence, we may compare these widely separated populations with our USAF sample, confident that any differences we find will be real.

Since every population contains some mature individuals who are small and others who are large, a comparison of populations really means a comparison of ranges of size. Anthropometric data for each dimension are commonly expressed mathematically as an average with its standard deviation, often with a table of percentiles (the range from smallest to largest divided into 100 equal parts, where the 50th percentile equals or closely approximates the average). But nonspecialists in statistics–most of us, that is–cannot easily visualize the actual differences between populations in those spare numbers; hence a more graphic comparison may be preferable.

If we lump the range of 100 percentiles into 4 equal parts or quartiles for each selected dimension of our 1950 USAF flying population, we set up a scale or yardstick of USAF body size by which we can assess the sizes found in other populations. Thus our lowest quartile contains the smallest 25 percentiles; our 2nd quartile, the 26th through the 50th, and so on. Let us now see how this works in the case of stature, our first comparison. (In the Tables that follow, IAF stands for Italian Air Force; RHAF, Royal Hellenic Air Force; TAF, Turkish Air Force; ROKAF, Republic of Korea Air Force; and JASDF, Japanese Air Self Defense Force.)

TABLE I
COMPARISON OF STATURE
(percentages in foreign populations relative to USAF quartiles)

	USAF[a]	IAF[b]		RHAF[b]		TAF[b]		ROKAF[c]		JASDF[d]
4.	(75 - 100)	7		7		4		1		1
3.	(50 - 75)	14		12		11		3		3
2.	(25 - 50)	24	79	25	81	20	85	21	96	12	96
1.	(0 - 25)	55		56		65		75		84	

a. Hertzberg et al., 1954 *b. Hertzberg et al., 1963*
c. Kay, 1961 *d. Oshima et al., 1962*

Here we see that more than three fourths of our Oriental groups, and more than half of our Mediterranean samples, are no larger than our 25th percentile; and that 96% of our Oriental sample and about 80% of our Mediterranean sample fall within our 50th percentile. Very few individuals of those populations are large enough to reach into our top quartile. We also note the trend toward increasing stature as we go from the East toward the tall populations of northwestern Europe.

Now let us look at weight.

TABLE II
COMPARISON OF WEIGHT
(percentages in foreign populations relative to USAF quartiles)

	USAF[a]	IAF[b]		RHAF[b]		TAF[b]		ROKAF[c]		JASDF[d]
4.	(75 - 100)	12		5		3		2		1
3.	(50 - 75)	21		15		11		6		2
2.	(25 - 50)	28	67	25	80	19	86	14	92	11	97
1.	(0 - 25)	39		55		67		78		86	

a. Hertzberg et al., 1954 *b. Hertzberg et al., 1963*
c. Kay, 1961 *d. Oshima et al., 1962*

Again the same trends are evident: more than 90% of the men in these Oriental samples, and 80% of the Turks and Greeks are within our 50th percentile. The tendency to increased weight among Italians for a given stature is seen in their somewhat reduced percentages; but even so it is clear that most of their people tend to be distinctly lighter than ours. And, as does stature, body weight shows a strong increasing trend from East to West.

These figures leave no doubt that our Air Force people—and hence the American source population—are distinctly taller and heavier than their counterparts among our Oriental or Mediterranean allies. This is confirmed by other studies (5, 6) which place us among the Norwegians, Scotsmen, and certain African groups who have been found to be among the world's tallest people.

But height and weight, though important, still do not represent the whole story. We must consider whether small men are merely scaled-down facsimiles of large men. If they are not, their body proportions may become critical when our Government furnishes smaller sizes of combat clothing, flying gear and other equipment to our Allies.

Let us look, therefore, at a few dimensions that are indicators of body proportions. One of these is sitting height (the height of the top of the head above the sitting surface when a man sits erect).

TABLE III
COMPARISON OF SITTING HEIGHT
(percentages in foreign populations relative to USAF quartiles)

	USAF[a]	IAF[b]		RHAF[b]		TAF[b]		ROKAF[c]		JASDF[d]
4.	(75 - 100)	11		14		12		19		13
3.	(50 - 75)	19		21		17		22		25
2.	(25 - 50)	27	70	30	65	27	71	29	59	37	62
1.	(0 - 25)	43		35		44		30		25	

a. Hertzberg et al., 1954 *b. Hertzberg et al., 1963*
c. Kay, 1961 *d. Oshima et al., 1962*

Here again we find that more than half of the men in each of our foreign samples are below our 50th percentile. But remembering that 96% of the Japanese and Korean flying personnel were no taller than our 50th percentile of stature, we find that, in sitting height, only about 60% are within that limit. This percentage drop is very important since it indicates that, for a given stature, Orientals tend to have torsos that are relatively longer than those of USAF personnel.

Since torsos differ, what about limb lengths? This question, if answered properly, immediately involves us in a comparison of the actual values themselves and particularly in a study of ratios of limb length to stature, sitting height and other dimensions. These additional details are beyond the scope of this article and have therefore been omitted. We may, however, indicate qualitative differences in both size and size distributions in the several populations, although they cannot tell the whole story.

Another important indicator of body proportions is buttock-knee length—the horizontal distance on a sitting man from the rear of his buttocks to the front of his knees.

TABLE IV
COMPARISON OF BUTTOCK-KNEE LENGTH
(percentages in foreign populations relative to USAF quartiles)

	USAF[a]	IAF[b]		RHAF[b]		TAF[b]		ROKAF[c]		JASDF[d]
4.	(75 - 100)	9		4		3		–		–
3.	(50 - 75)	16		9		8		–		–
2.	(25 - 50)	25	75	24	87	19	89	3	100	–
1.	(0 - 25)	50		63		70		97		–

a. Hertzberg et al., 1954 *b. Hertzberg et al., 1963*
c. Kay, 1961 *d. Oshima et al., 1962*

Although this dimension was not taken on the Japanese sample, we see that 97% of the South Koreans (who are similar in build to the Japanese) are within our 25th percentile, and that all are within our 50th, with high percentages among the Turks and Greeks, and fairly high incidence among the Italians. Again the trend is to greater lengths as we proceed from East to West.

Gluteal furrow height—the distance, on a standing man, from the floor to the furrow under his gluteal muscle—is a close approximation to total leg length. Unfortunately, this dimension also is not available in our present data sample of the Japanese.

TABLE V
COMPARISON OF GLUTEAL FURROW HEIGHT
(percentages in foreign populations relative to USAF quartiles)

	USAF[a]	IAF[b]		RHAF[b]		TAF[b]		ROKAF[c]		JASDF[d]
4.	(75 - 100)	7		4		3		–		–
3.	(50 - 75)	15		9		10		1		–
2.	(25 - 50)	23	78	20	87	22	87	8	99	–
1.	(0 - 25)	55		67		65		91		–

a. Hertzberg et al., 1954 *b. Hertzberg et al., 1963*
c. Kay, 1961 *d. Oshima et al., 1962*

Again the picture remains the same; the South Koreans have the shortest legs relative to our own, and the Mediterraneans are close behind in this respect. And again there is the clear increase from East to West.

Because the hand is so important in doing anything, gloves comprise a large part of the equipment our Government furnishes to our allies. Let us examine hand length and hand breadth.

TABLE VI
COMPARISON OF HAND LENGTH
(percentages in foreign populations relative to USAF quartiles)

	USAF[a]	IAF[b]		RHAF[b]		TAF[b]		ROKAF[c]		JASDF[d]	
4.	(75 - 100)	22		16		17		3		5	
3.	(50 - 75)	25		23		24		12		14	
2.	(25 - 50)	25	53	26	61	25	59	18	85	23	81
1.	(0 - 25)	28		35		34		67		58	

a. Hertzberg et al., 1954 *b. Hertzberg et al., 1963*
c. Kay, 1961 *d. Oshima et al., 1962*

Hands tend to be short in the Oriental samples, as might be expected from their relatively short stature. The Mediterraneans, however, despite their smaller bodies, come fairly close to USAF dimensions, thereby showing an appreciable change in body proportions from the USAF type. Again we see the familiar trend from East to West, the Italians nearly approximating the USAF distribution.

Remembering those percentages, we may now look at hand breadth.

TABLE VII
COMPARISON OF HAND BREADTH
(percentages in foreign populations relative to USAF quartiles)

	USAF[a]	IAF[b]		RHAF[b]		TAF[b]		ROKAF[c]		JASDF[d]	
4.	(75 - 100)	31		21		14		2		17	
3.	(50 - 75)	21		21		18		8		15	
2.	(25 - 50)	26	48	29	58	27	68	23	90	24	68
1.	(0 -25)	22		29		41		67		44	

a. Hertzberg et al., 1954 *b. Hertzberg et al., 1963*
c. Kay, 1961 *d. Oshima et al., 1962*

A considerable percentage of hand breadths range into the two top quartiles among the Japanese, despite the small number of long hands among them. This indicates a change from other trends, hence a change in body proportion. The South Koreans continue to display relatively short and narrow hands. The trend from East to West is still apparent, with the added interesting point that the Italians tend to have an even higher percentage of the widest hands than the USAF. Thus again we find a change in body proportion in a different direction. Hands, of course, and feet also, are affected perhaps more than other body members by the amount of manual work performed; and so, in a detailed analysis, one would desire more data than are available in these surveys on the socioeconomic backgrounds of the subjects. Nevertheless, the essential point is that body proportions are not constant, and the direction of change is not constant, either.

Foot length and foot breadth are interesting here because of their importance in shoe size.

TABLE VIII
COMPARISON OF FOOT LENGTH
(percentages in foreign populations relative to USAF quartiles)

	USAF[a]	IAF[b]		RHAF[b]		TAF[b]		ROKAF[c]		JASDF[d]
4.	(75 - 100)	18		15		13		–		–
3.	(50 - 75)	24		22		20		3		–
2.	(25 - 50)	25	58	25	63	28	67	7	97	–
1.	(0 - 25)	33		38		39		90		–

a. Hertzberg et al., 1954 *b. Hertzberg et al., 1963*
c. Kay, 1961 *d. Oshima et al., 1962*

Once again, as expected, we find that nearly all of the South Korean subjects fall below our 50th percentile; and that, as we go West toward Europe, the foot lengths approach our own, though they are still somewhat shorter. Let us now examine foot breadth.

TABLE IX
COMPARISON OF FOOT BREADTH
(percentages in foreign populations relative to USAF quartiles)

	USAF[a]	IAF[b]		RHAF[b]		TAF[b]		ROKAF[c]		JASDF[d]
4.	(75 - 100)	68		61		61		23		–
3.	(50 - 75)	19		23		21		33		–
2.	(25 - 50)	9	13	10	16	10	18	20	44	–
1.	(0 - 25)	4		6		8		24		–

a. Hertzberg et al., 1954 *b. Hertzberg et al., 1963*
c. Kay, 1961 *d. Oshima et al., 1962*

Here we encounter an astonishing reversal of the trend. In general, the compared samples have fewer narrow feet, and more wide feet, than we do. The percentage of extremely wide feet increases as we go from East toward Europe, while the incidence of narrow feet declines sharply. Whatever the reasons, it is clear that their feet are different

from ours in shape and development. If we send them shoes built to our sizes and size distributions, will every one of them receive a good fit? Indeed, unless many of them are willing to squeeze their feet painfully into ill-fitting shoes, we can see that a large part of our materials, labor and money may be wasted.

Let us take a final look at just one head dimension, since the head is an important element in body proportions. Head circumference is a major indicator of head size, all hats being scaled according to it.

TABLE X
COMPARISON OF HEAD CIRCUMFERENCE
(percentages in foreign populations relative to USAF quartiles)

	USAF[a]	IAF[b]	RHAF[b]	TAF[b]	ROKAF[c]	JASDF[d]
4.	(75 - 100)	11	5	2	6	9
3.	(50 - 75)	23	12	8	14	21
2.	(25 - 50)	27 } 66	20 } 83	17 } 90	27 } 80	27 } 70
1.	(0 - 25)	39 }	63 }	73 }	53 }	43 }

a. Hertzberg et al., 1954 *b. Hertzberg et al., 1963*
c. Kay, 1961 *d. Oshima et al., 1962*

Thus these heads, in general, are smaller than those in the USAF sample; but the percentages upset even the repeated trends of increase from East to West. Although head circumference is not the only important head dimension, we may neglect the others because there is virtually no meaningful correlation between any of the dimensions of the head and face. Suffice it to say that the standard USAF pressure helmet, which is made in only one shell size with various liner sizes, is most unlikely to prove satisfactory for our Mediterranean and Oriental allies.

This brief review shows quite conclusively that our Air Force people (and hence, our population at large) are giants as compared to these other populations. Not only is the large majority of the flying personnel among our Mediterranean and Oriental allies below our 50th percentile in most dimensions, showing that their sizes are different from ours, but also their proportions are different. Hence, smaller sizes of garments which fit us will not necessarily fit all of them adequately. In any case, it is inescapable that reliable anthropometric data on such populations are essential to the effective solution of the vexing and expensive fitting problems associated with clothing and equipment furnished our allies under our aid programs.

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Mr. Hertzberg measuring a subject's ear.

Constellation on the Roof: The rather imposing model airplane on the roof of AFCRL—actually, a Constellation scaled to one-tenth actual size—was not put there for decorative purposes, but is being used to test a new airborne antenna developed by AFCRL's Microwave Physics Laboratory. The airplane model contains a novel antenna which is also scaled to one-tenth size. This model airplane is being used to test the antenna prior to the installation of operational antennas in Constellation aircraft.

the KC-135
AFCRL's FLYING LABORATORY

Scores of observing ports have been cut into the side of this KC–135 to accommodate a range of scientific instrumentation. The KC–135 is one of six flying laboratories operated by AFCRL. This particular flying laboratory is instrumented to study the transmission and attenuation of optical energy through the atmosphere. Equipments aboard the aircraft include an electron scan spectrometer, an infrared sky mapper, five Michelson interferometers, two infrared radiometers, as well as all–sky and documentary cameras and several photometers. With this aircraft, AFCRL scientists make observations all over the world. In March 1969, flights are scheduled for Alaska and Hawaii. In May, observations will be made with the plane operating out of Torrejon, Spain; and in July, flights are scheduled for Thule and the Canal Zone.